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Study on the Effect of Power Generation Benefit Triggered by Hydrological Characteristics Because of Dam Construction

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Abstract

In this paper, on the basis of subentry investigation method and combining river basin characteristics, an improved subentry investigation method has been established. In order to realize watershed runoff capacity reductive, keeping water balance is a key step. In a close watershed, after dam construction real runoff capacity flowing from a controlled river cross section equals actual measured runoff capacity in the cross section adding reductive water volume in upstream cross section. According to many researches, reductive water volume is affected by social development, population increases, land use characteristics, forest area, evaporation, seepage and so on. The new method considering many calculating factors and abiding by the principle of water balance provides a gist for studying on the effect of power generation benefit triggered by hydrological characteristics because of dam construction.

Keywords: dam construction; hydrological characteristics; power generation benefit; runoff restoration; subentry investigation method

1. Introduction

Although dam plays important roles in production activity and economic life, local natural runoff characteristics and processes are changed because of dam construction. After dam construction, in order to fully take advantage of dam benefits, the reservoir of dam undertakes huge flood regulation and storage. As a result, the downstream runoff of river will change obviously. Many researches show that dam construction affects local climate and economic and social development [1,2]. After dam construction,

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reservoir regulation and storage capability probability distribution of river runoff have changed. So, before and after completion of dam, we have to pay close attentions to use hydrological series data. In order to gain whole series hydrological data of river runoff, hydrological reductive method can be used. At present, in the field of hydrological reductive runoff capacity reductive is the hotspot. After dam construction, land use efficiency changes largely resulted in urbanization. At the same time, irrigation condition has been improved which leads to evaporation increasing since enlarged water surface. Above-mentioned factors can affect upstream natural runoff. If each year water consumption brought by these factors after dam construction should be calculated, then effect of power generation benefit triggered by hydrological characteristics because of dam construction will be known

2. A summary of runoff capacity reductive methods

In practical application, common used methods of river runoff capacity reductive include subentry investigation method, evaporation differential value method, rainfall-runoff relationship method, hydrological simulation method, empirical formula method and so on[3,4].

(1) Evaporation differential value method

This method is suitable for hydrological reductive under condition of long periods of time. Through neglecting changes of water storage capacity in watershed the method just takes changes of evaporation as reductive value because of human activities.

(2) rainfall-runoff relationship method

This method is realized by establishing the relationship between rainfall and runoff capacity data in a river cross section in which does not suffer human activities.

(3) Hydrological simulation method

The theory basis of this method is runoff theory. In China humid region, Xinanjiang Model can be used because of its good physical and theoretical base. Usually, this method often apply daily runoff for runoff reductive calculation.

(4) Subentry investigation method

By means of computing unmeasured water volume and then adding actual measured runoff capacity, natural runoff capacity will be reduced. This method have enough accuracy and good application effect. However, how to collect large amount of hydrological data is a challenge problem.

(5) Empirical formula method

The relationship between needed calculation hydrological eigenvalue and other hydrological, terrain parameters should be firstly constructed for the sake of calculating project needed hydrological eigenvalue.

On the basis of above mentioned methods, combining watershed characteristics, an improved subentry investigation method has been put forward which considers different calculation indices based on water balance in this paper.

3. Theory of improved subentry investigation method

According to foregoing description about runoff reductive methods, in practical calculation, in order to realize watershed runoff capacity reductive keeping water balance is a key step. In a close watershed, after dam construction real runoff capacity flowing from a controlled river cross section equals actual measured runoff capacity in the cross section adding reductive water volume in upstream cross section(reductive water volume affected by social development, population increases, land use characteristics, forest area, evaporation, seepage and so on)[5,6]. Only if each part of water consumption is computed, the relation between real runoff capacity and actual measured runoff capacity will be established. The relation can be expressed by formula as follows(unit:mm):

$$W_{nat} = W_{mea} + W_{red} \tag{1}$$

Where:

$$W_{nat} = W_{mea} + W_{agr} + W_{ind} + W_{liv} + W_{eva} + W_{sep} + W_{lad} \pm W_{yin} \pm W_{div} \tag{2}$$

That is:

$$W_{red} = W_{agr} + W_{ind} + W_{liv} + W_{eva} + W_{sep} + W_{lad} \pm W_{yin} \pm W_{div} \tag{3}$$

Where, W_{nat} is real runoff capacity in controlled cross section, W_{mea} stands for actual measured runoff capacity in controlled cross section. W_{agr} is agricultural water consumption each year, W_{ind} is industrial water consumption, W_{liv} is defined as domestic water consumption, W_{eva} is difference value between surface evaporation and land surface evaporation, W_{sep} stands for seepage amount in watershed, W_{lad} is water consumption of lands and forest areas, W_{yin} is diverting water volume, if diverting water from other watershed to present watershed, the value is positive and vice versa. W_{div} is flood diversion volume, if diverting flood water from other watershed to present watershed, the value is positive and vice versa. Here the definite expression of different parts can refer to some relevant literature.

For simplifying calculation process, we change unit mm into m^3/s ,taking W_{nat} as an example, the transferring process is listed as follows:

$$Q_{nat} = \frac{W_{nat} \times F \times 10^6}{1000 \times 365 \times 24 \times 2600} \tag{4}$$

Where, F stands for total area of watershed(unit: km^2). Similarly, through formula(4) other indices are also can be transferred and expressed by unit m^3/s .

4. Example

A hydropower station locates in middle and lower Yangtze River region, the water-collecting area of power station is 8983 km^2 , mean annual water head of dam is 95m. In this area, mean annual precipitation is about 1800mm. In the basin of power station, there are 270 small dams and total water surface area occupies 10% of the basin area. At the same time, forestry lands is about 10% of total basin area, farmland area is about 50%, other areas including urban area, roads and flood plain are about 30% of total area of this basin. At present, 70 years hydrological series data is in detail. In 1976, urban residents are 100 thousands and countryside populations are 400 thousands. There are 30 thousands heads of livestock and GDP each year is about 1.332 billion yuan. Producing 10 thousands yuan GDP needs 30 cubic meters water. The natural increasing ratio of population each year is 0.6%, the livestock is 1%, GDP increasing ration each year is 7%. On the contrary, forestry lands decreasing ratio per year is 2%. Because climate changing, increasing ration of irrigation area is about 1% and each year about 1% farmlands is used by social development. In the basin, water consumption of urban people per day is 100l/d and countryside people and each head of livestock use 50l/d per day. Form 1976 to now, diverting water actions has not happened.

In order to precisely calculate reductive runoff capacity, in this paper actual measured runoff capacity in controlled cross section from 1976 to 1999 has been selected(Tab.1).

Table 1. actual measured runoff capacity in controlled cross section from 1976 to 1999（mm）

year	1976	1977	1978	1979	1980	1981	1982	1983
Flow rate	1516.6	1633.7	1550.8	1288.1	1296.8	1293.8	931.1	1048.2
year	1984	1985	1986	1987	1988	1989	1990	1991
Flow rate	1253.8	1419.5	1416.6	1867.9	1545.2	1682.3	1822.2	1410.9
year	1992	1993	1994	1995	1996	1997	1998	1999
Flow rate	1876.5	1756.5	891.1	1028.2	1122.5	1036.8	1033.9	1179.6

According to formula (1) to (4) and combining power station basin relevant data, the reductive results are listed in tab.2 as follows:

Table 2. Reductive results of basin（mm）

year	Actual measured results	Industrial reductive water	People and livestock consumption reductive water	Agricultural reductive water	Forestry lands reductive water	Evaporation reductive water	Total reductive water	Final real runoff capacity
1976	1516.6	0.445	0.268	2.400	0.100	0.100	3.313	1519.913
1977	1633.7	0.481	0.538	2.424	0.098	0.200	3.741	1637.441
1978	1550.8	0.519	0.809	2.448	0.096	0.299	4.171	1554.971
1979	1288.1	0.561	1.082	2.473	0.094	0.395	4.605	1292.705
1980	1296.8	0.605	1.357	2.498	0.092	0.489	5.041	1301.841
1981	1293.8	0.654	1.633	2.523	0.090	0.588	5.488	1299.288
1982	931.1	0.706	1.911	2.548	0.088	0.683	5.936	937.036
1983	1048.2	0.763	2.190	2.573	0.086	0.777	6.389	1054.589
1984	1253.8	0.824	2.469	2.599	0.084	0.868	6.844	1260.644
1985	1419.5	0.889	2.749	2.625	0.082	0.960	7.305	1426.805
1986	1416.6	0.961	3.028	2.651	0.080	1.051	7.771	1424.371
1987	1867.9	1.038	3.309	2.678	0.078	1.139	8.242	1876.142
1988	1545.2	1.121	3.591	2.705	0.076	1.228	8.721	1553.921
1989	1682.3	1.210	3.874	2.732	0.074	1.316	9.206	1691.506
1990	1822.2	1.307	4.157	2.759	0.072	1.403	9.698	1831.898
1991	1410.9	1.412	4.441	2.780	0.070	1.496	10.199	1421.099
1992	1876.5	1.525	4.726	2.815	0.068	1.574	10.708	1887.208
1993	1756.5	1.647	5.012	2.843	0.066	1.659	11.227	1767.727
1994	891.1	1.778	5.298	2.872	0.064	1.743	11.755	902.855
1995	1028.2	1.920	5.585	2.900	0.062	1.827	12.294	1040.494
1996	1122.5	2.074	5.873	2.929	0.061	1.907	12.844	1135.344
1997	1036.8	2.240	6.162	2.958	0.060	1.989	13.409	1050.209
1998	1033.9	2.419	6.286	2.988	0.058	2.070	13.821	1047.721
1999	1179.6	2.613	6.592	3.018	0.057	2.149	14.429	1194.029

From table 2 we can find that water consumption in industrial and agricultural production increases gradually each year. However, forestry lands water utility decreases slightly because social development damages local environment and vegetations. Generally, after dam construction real runoff capacity shows decreasing tendency brought by agricultural and industrial development, populations increasing. The total decrement is about 2-3% of real runoff capacity of river.

According to mathematical statistics, supposing annual real runoff capacity of river $(W_{nat,1}, W_{nat,2}, \cdots, W_{nat,n})$ is a group of random variables. After dam construction, based on formula(1):

$$W_{nat,i} = W_{mea,i} + W_{red,i} \quad (i = 1,2,\cdots,n) \tag{5}$$

According to annual reductive runoff capacity of river $(W_{red,1}, W_{red,2}, \cdots, W_{red,n})$, actual measured runoff capacity of river $(W_{mea,1}, W_{mea,2}, \cdots, W_{mea,n})$ can be calculated.

According to tab.2 expect value of real runoff capacity can be calculated, here $E(W_{nat,i}) = 1379.6$ (mm). Based on formula (5), the formula can be changed into $E(W_{mea,i}) = E(W_{nat,i}) - W_{red,i}$ （$i = 1,2,\cdots,n$）. if expect value of real runoff capacity is obtained, then expect value of actual measured runoff capacity will be computed. With time going by the available water for power generation each year decreases gradually. After interpolation fitting expect value of actual measured capacity can be expressed by quadratic parabola function $E(W_{mea,i}) = -0.003t^2 + 11.309t - 9387.5$.

5. Conclusion

With the lapse of time, the expect value of actual measured runoff capacity will gradually decreases and this part of water has close relation with benefit of power generation. Supposing water head H and power generation time T_{power} keeping instant, according to formula

$$Q_{power} = 9.81\eta E(W_{mea,i}) \times H \times T_{power},$$

here η is power generation efficiency. We can know that the changing curve of power generation each year is completely consistent with $E(W_{mea,i})$, just value is different. It indicates that power generation benefit will decline gradually because social development and populations increasing.

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